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DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
K.U.LEUVEN - BELGIUM

AGU FALL MEETING
San Francisco | 14 – 18 December 2015

On the Contribution of Clouds to Greenland Ice Sheet Mass Loss

K. Van Tricht, S. Lhermitte, J. Lenaerts, I. Gorodetskaya, T. L'Ecuyer, B. Noël, M. van den Broeke, D. Turner and N. van Lipzig

KU Leuven
Department of Earth and Environmental Sciences
Division of geography, regional climate studies group
Kristof.VanTricht@ees.kuleuven.be

Clouds over the ice sheets

Why do we want to get them right?

Radiative fluxes → Surface energy budget → **Surface temperature** → (Surface) mass balance

Precipitation → (Surface) mass balance → **Global sea level**

Clouds over the ice sheets

Why do we want to get them right?

Radiative fluxes

Precipitation

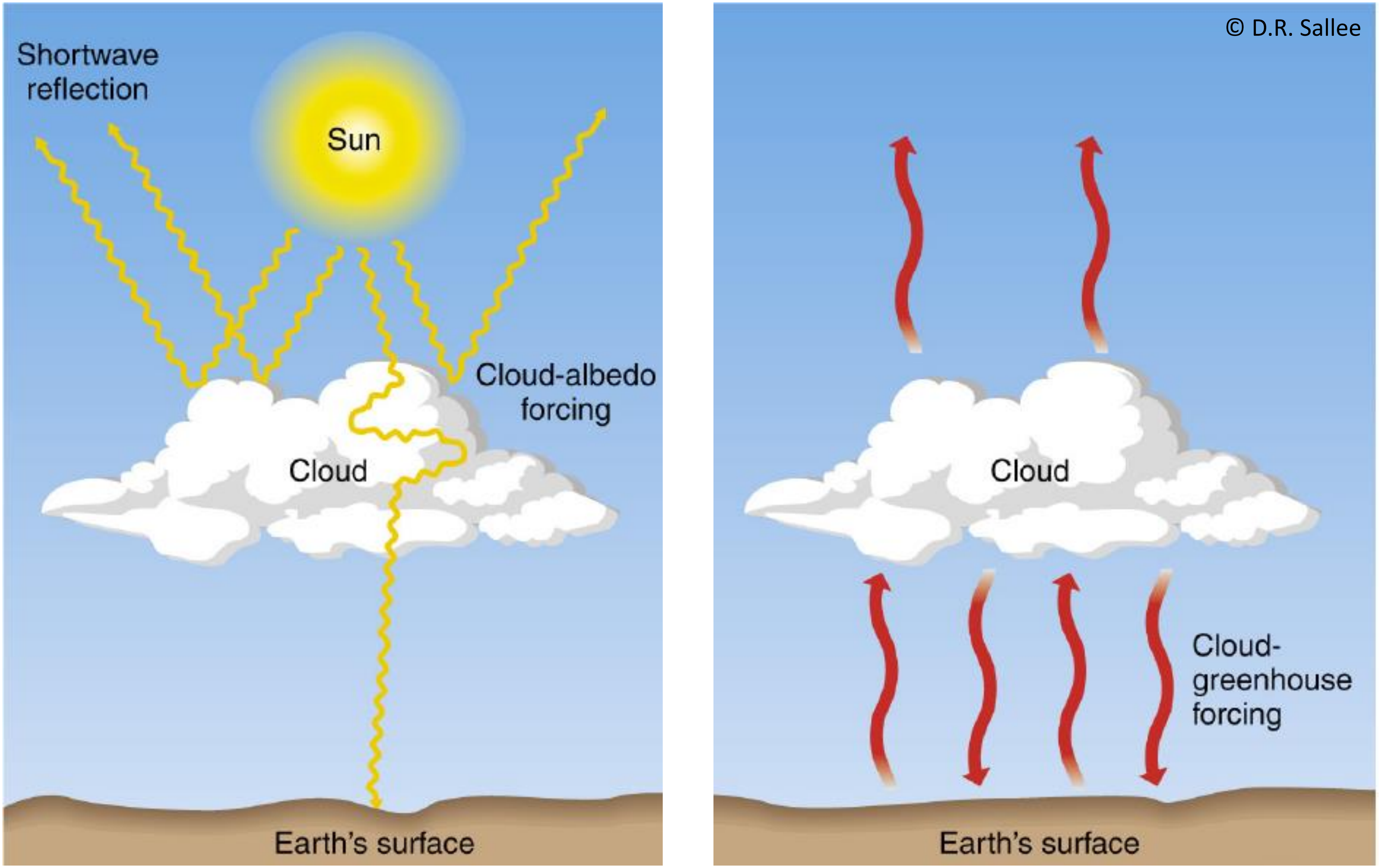
Surface energy budget

(Surface) mass balance

Surface temperature

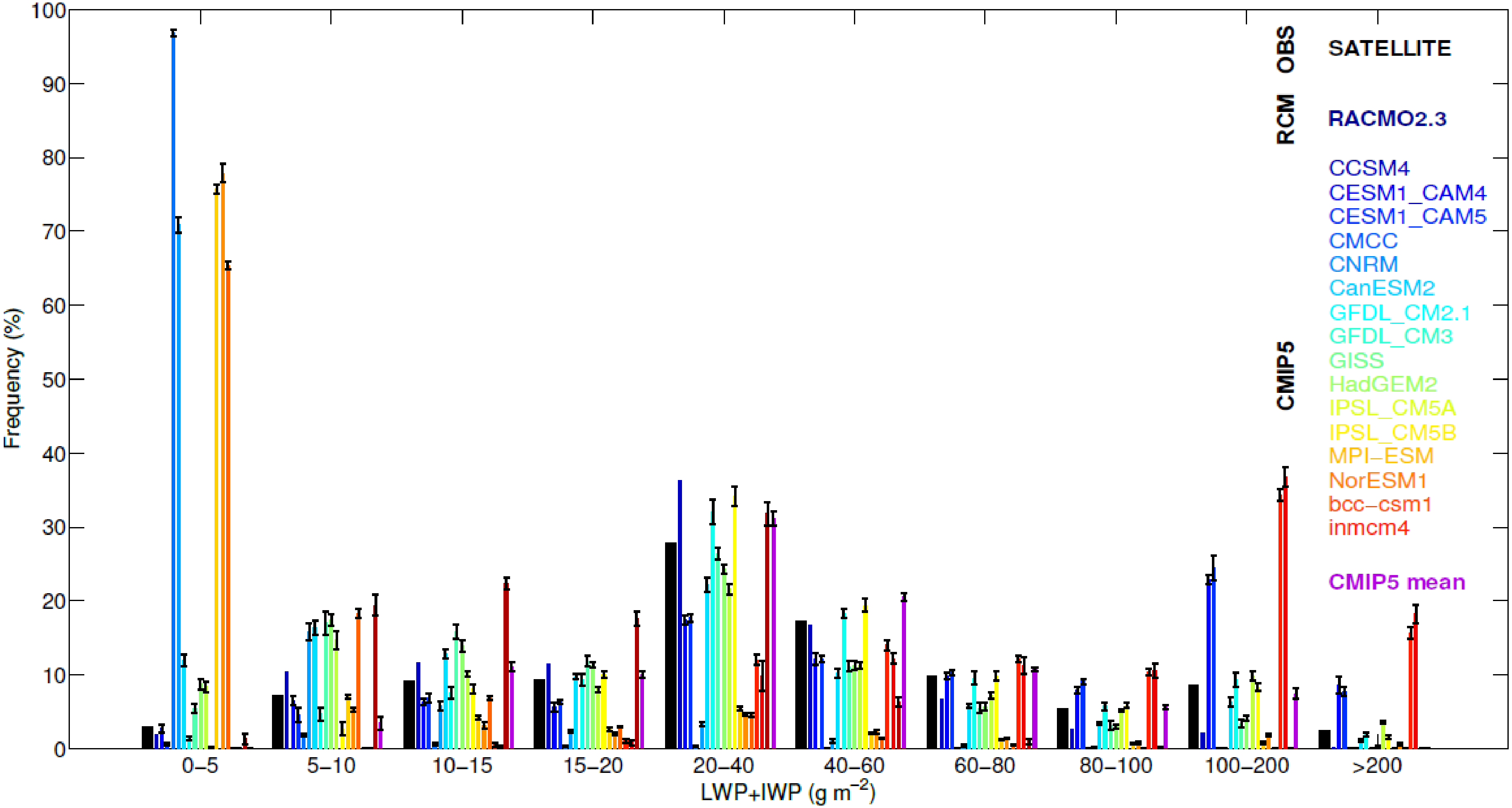
Global sea level

Clouds affecting the energy budget



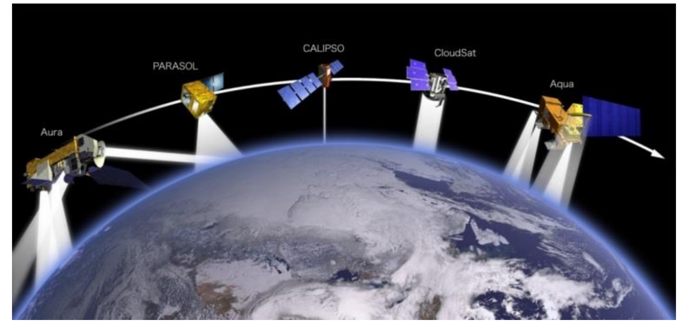
SW cooling ↔ **LW warming**

Clouds in climate models



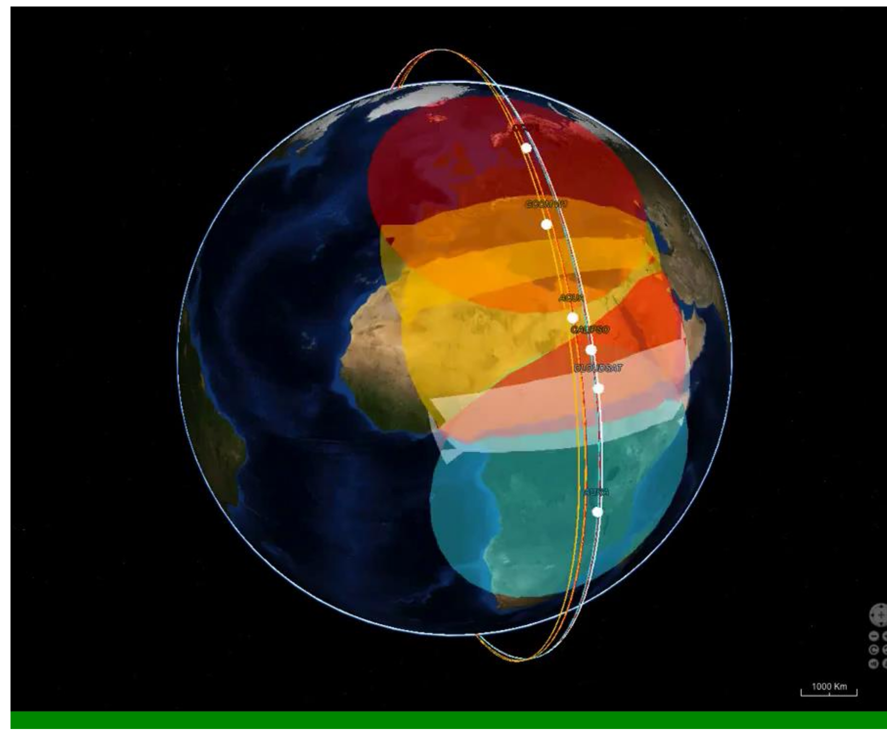
Van Tricht et al., 2015 (in press)

A-train constellation



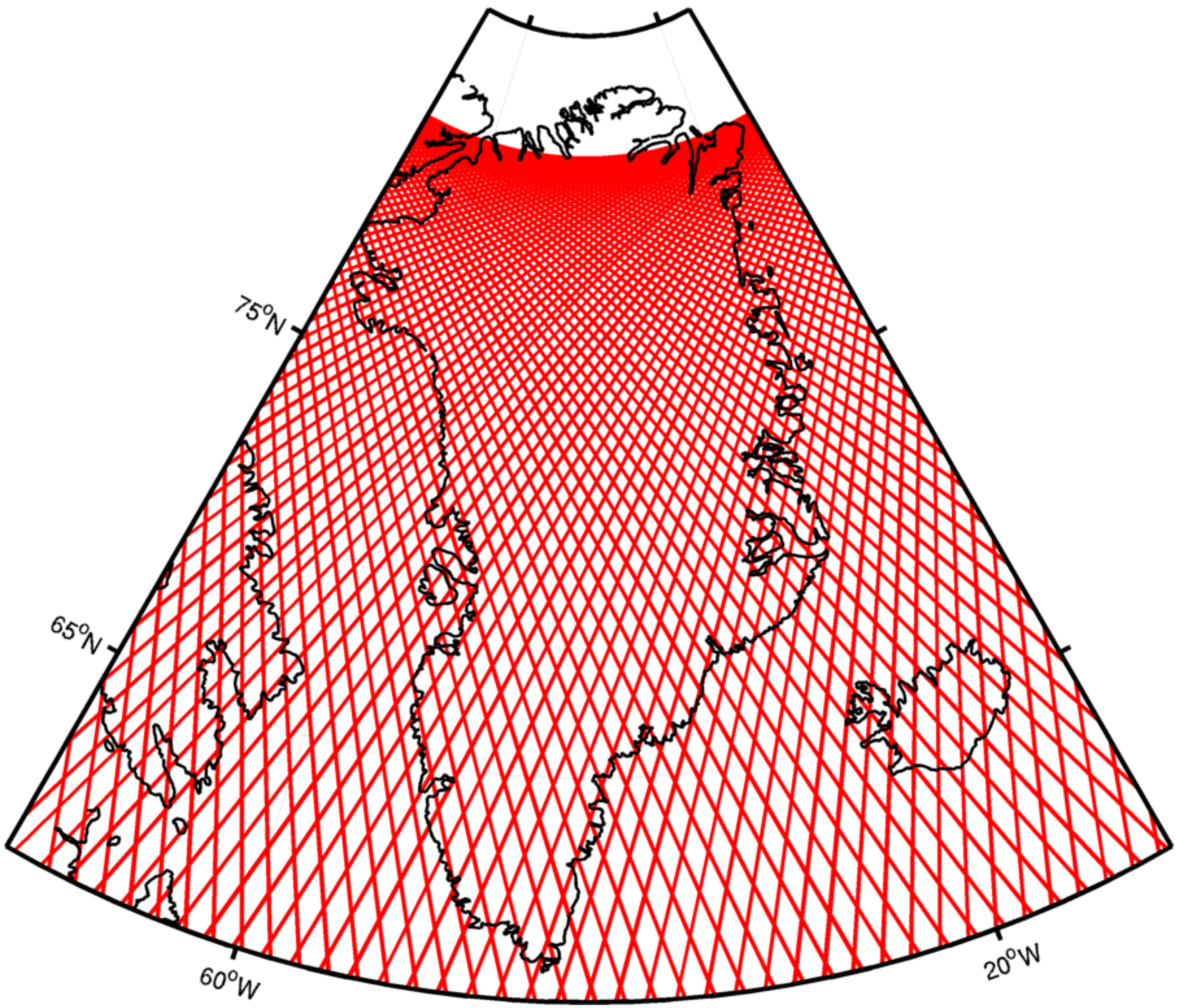
CloudSat and CALIPSO

- Combination of active radar and lidar
- Macro- and microphysical cloud properties
- Vertically-resolved

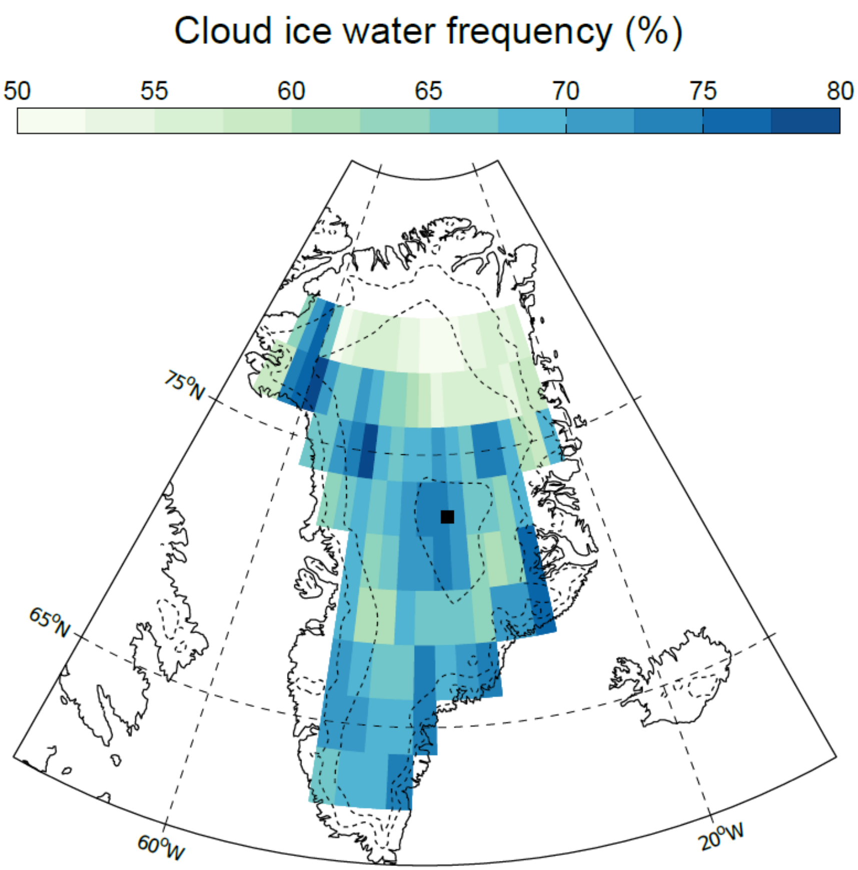


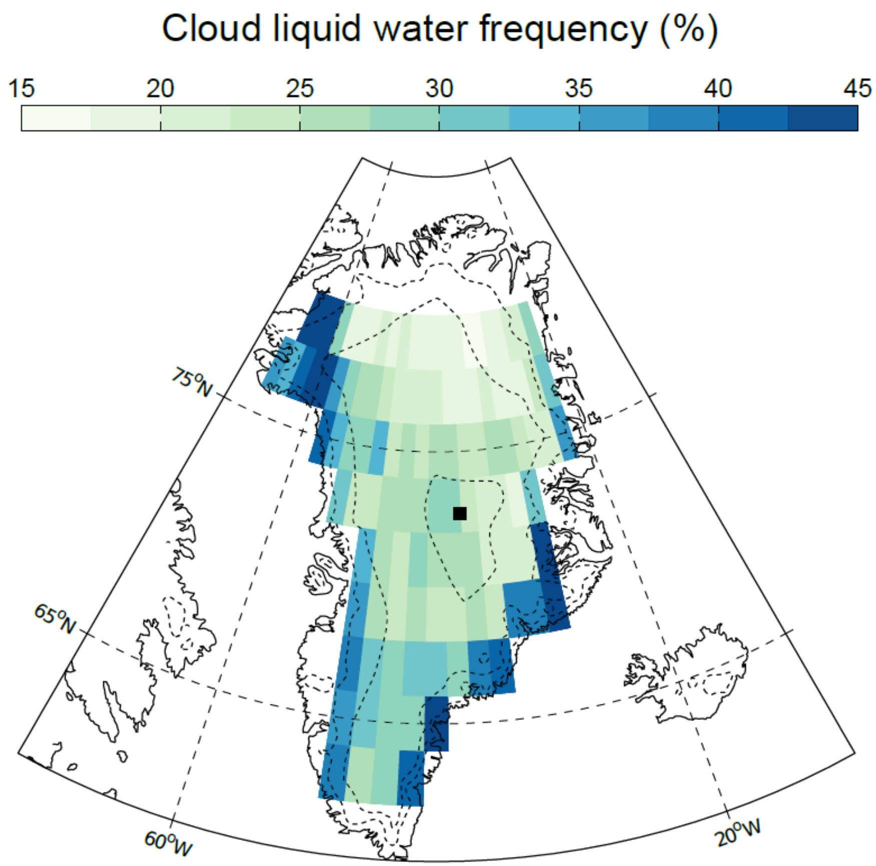
T. Rice, youtube.com

CloudSat/CALIPSO overpasses



Retrieved cloud properties

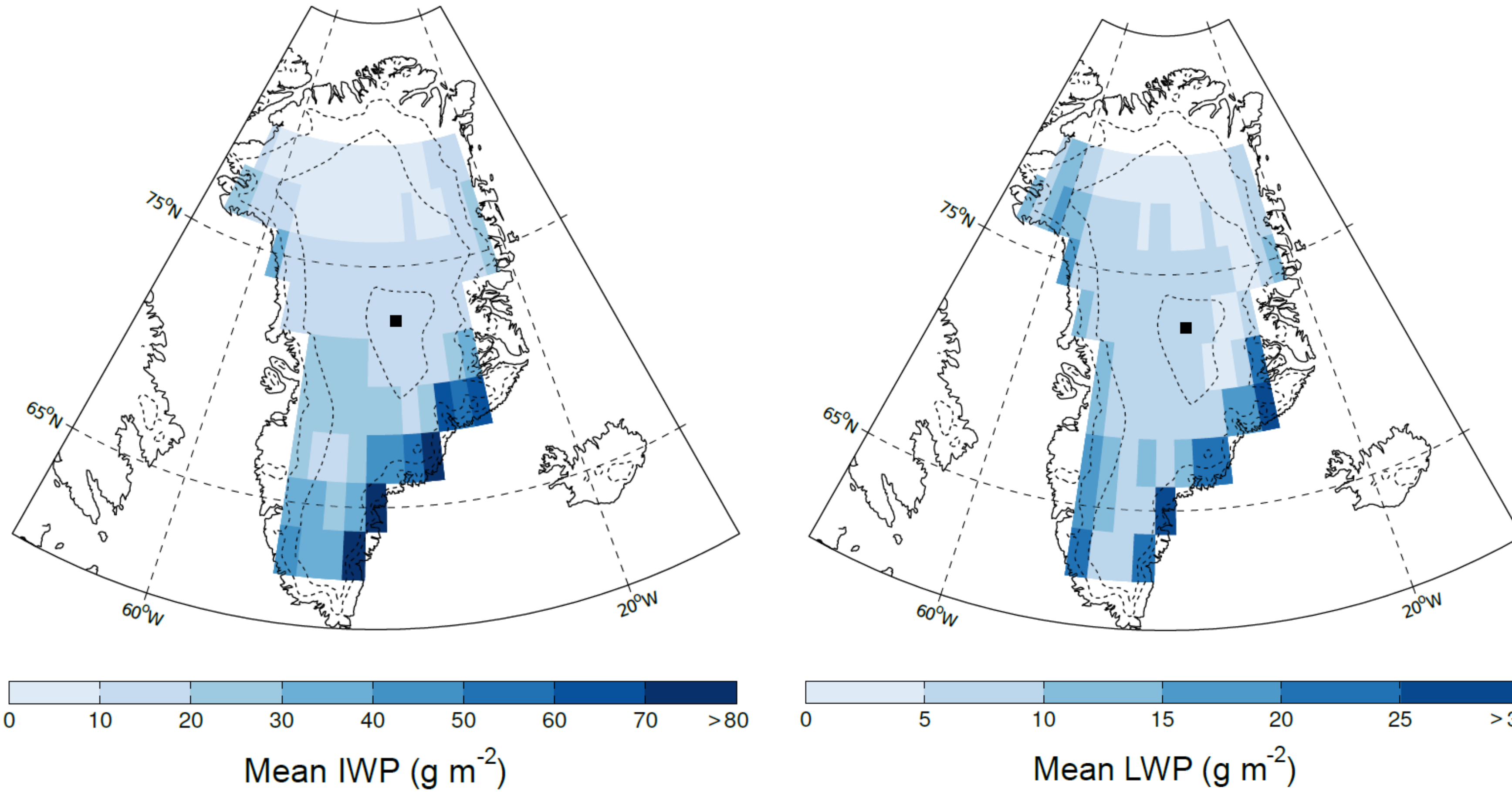




Macrophysical properties

Van Tricht et al., 2015 (in press)

Retrieved cloud properties



Microphysical properties

Van Tricht et al., 2015 (in press)

2B-FLXHR-LIDAR

The level-2 "Fluxes and Heating Rates" product

(Henderson *et al.*, 2013)

Every vertical profile

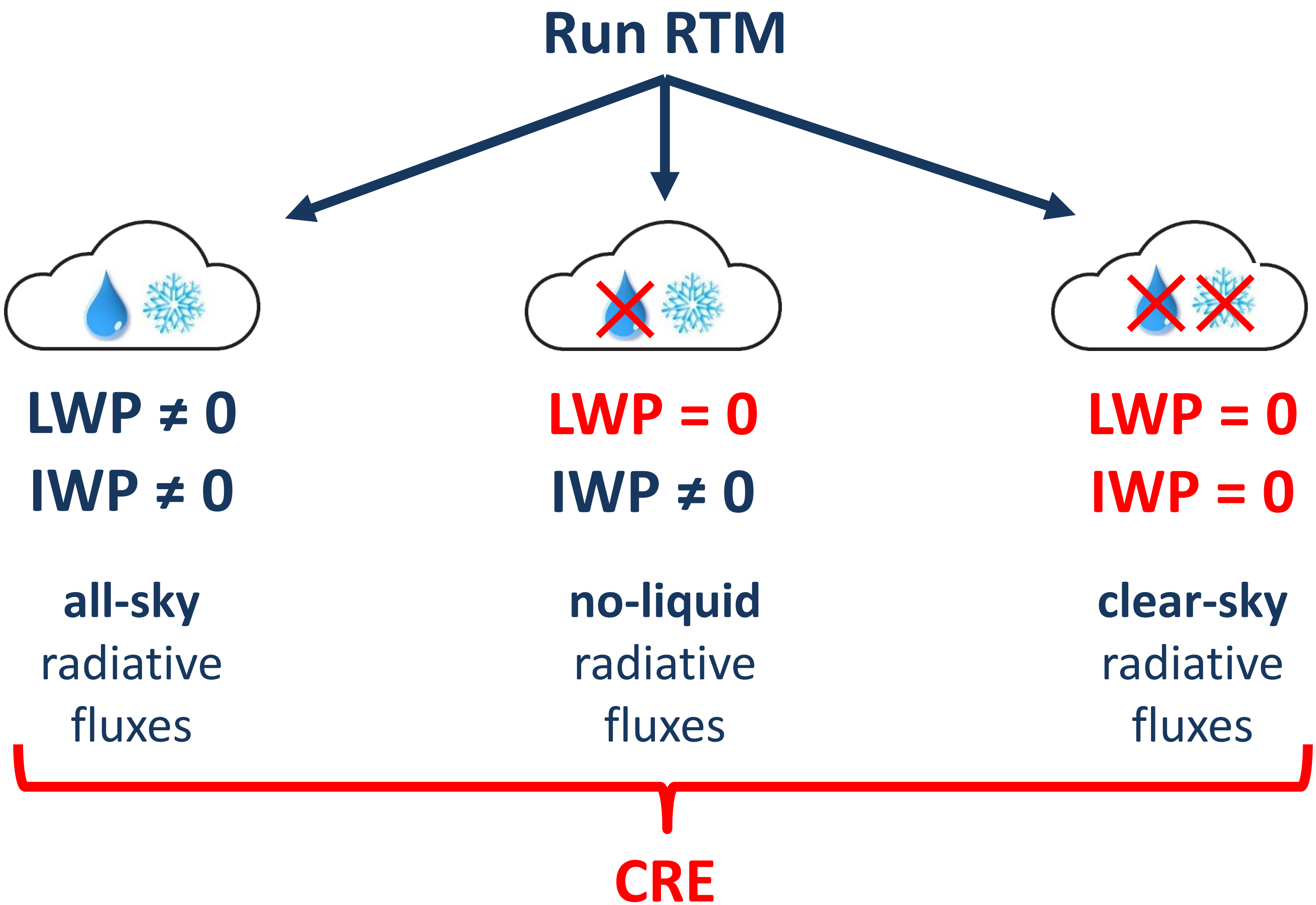
CloudSat/CALIPSO determined LWP/IWP

ERA-Interim humidity and temperature profiles

Two-stream RTM

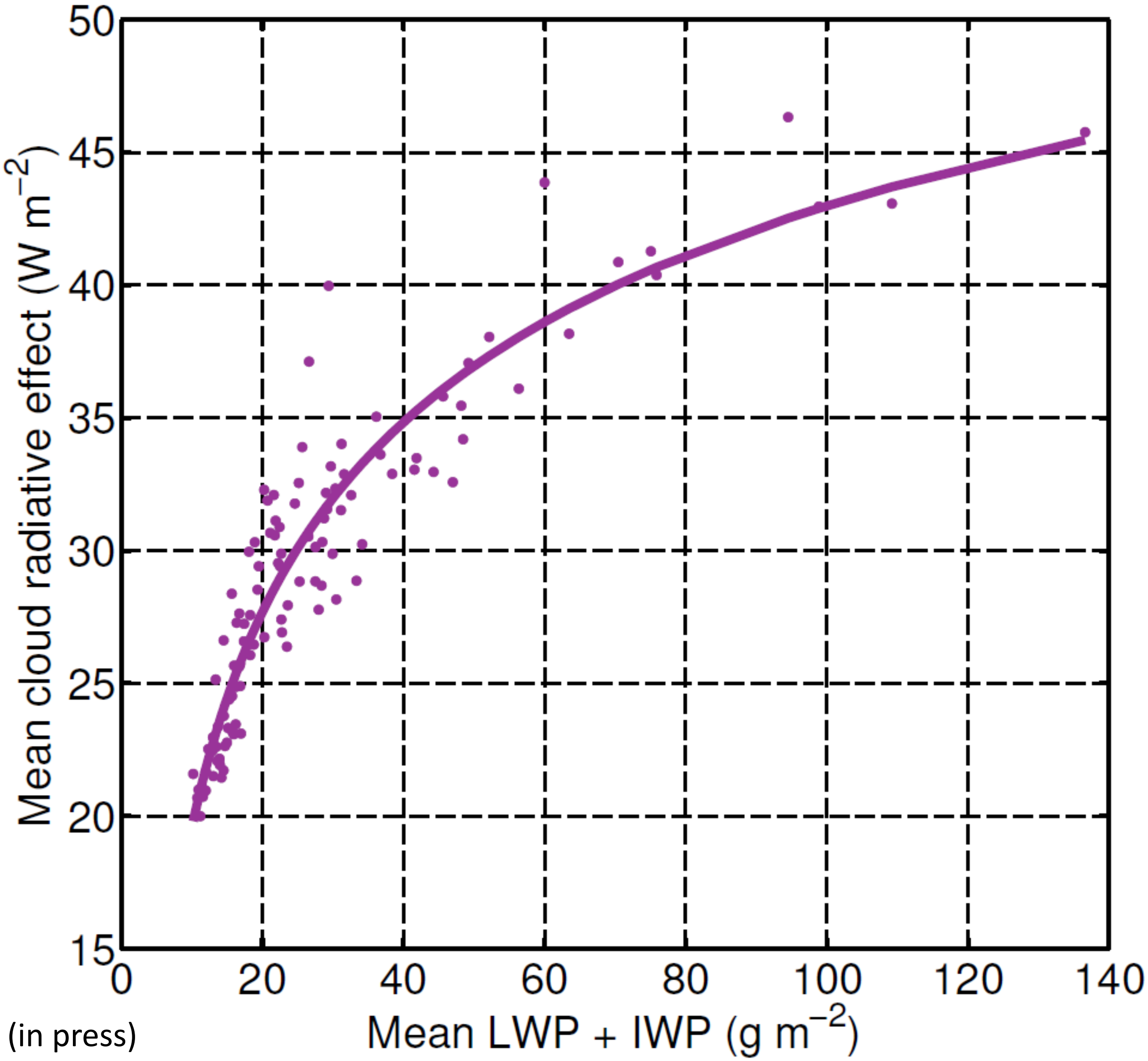
Broadband LW/SW radiative fluxes

Cloud radiative effect



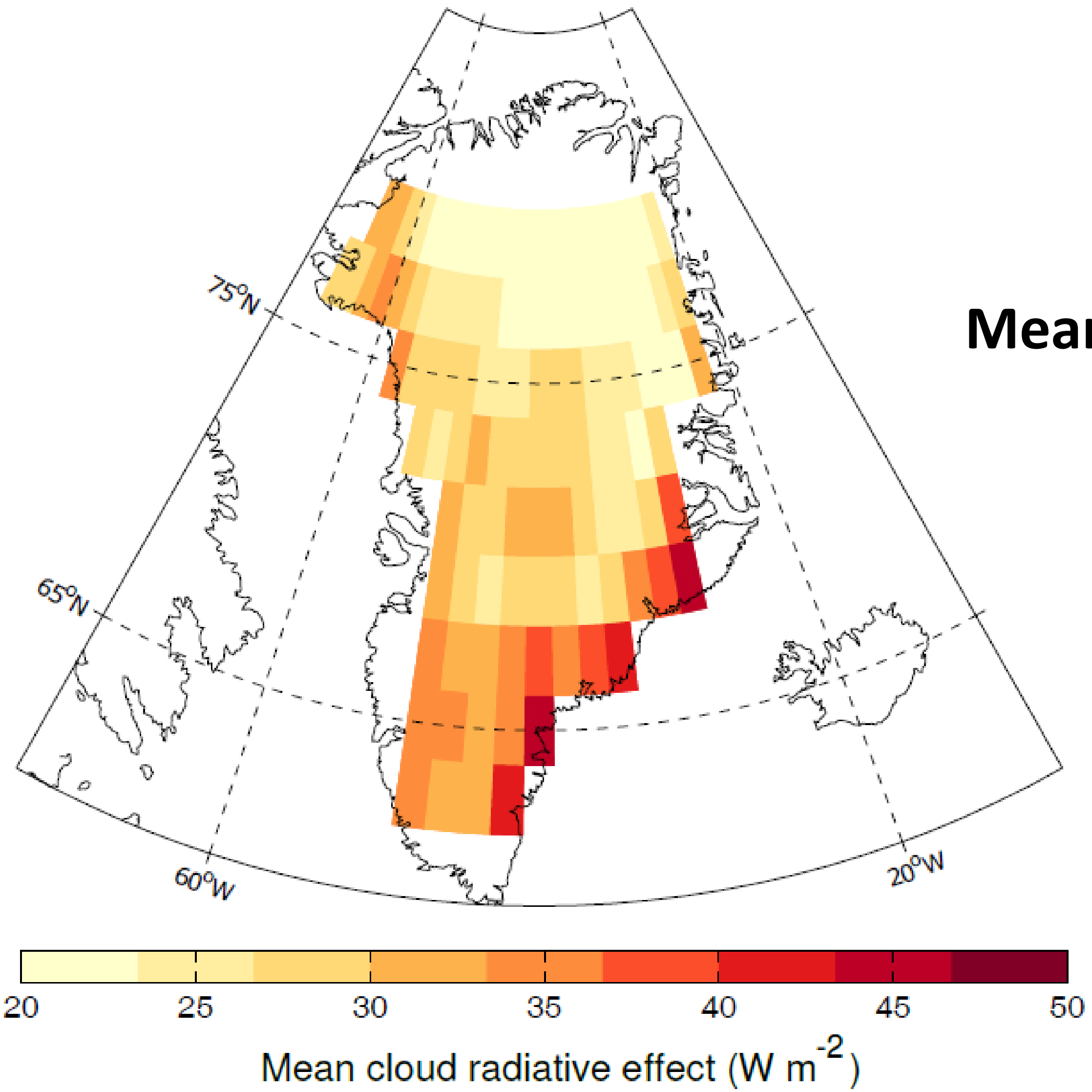
Cloud radiative effect

2007-2010



Van Tricht et al., 2015 (in press)

Cloud radiative effect

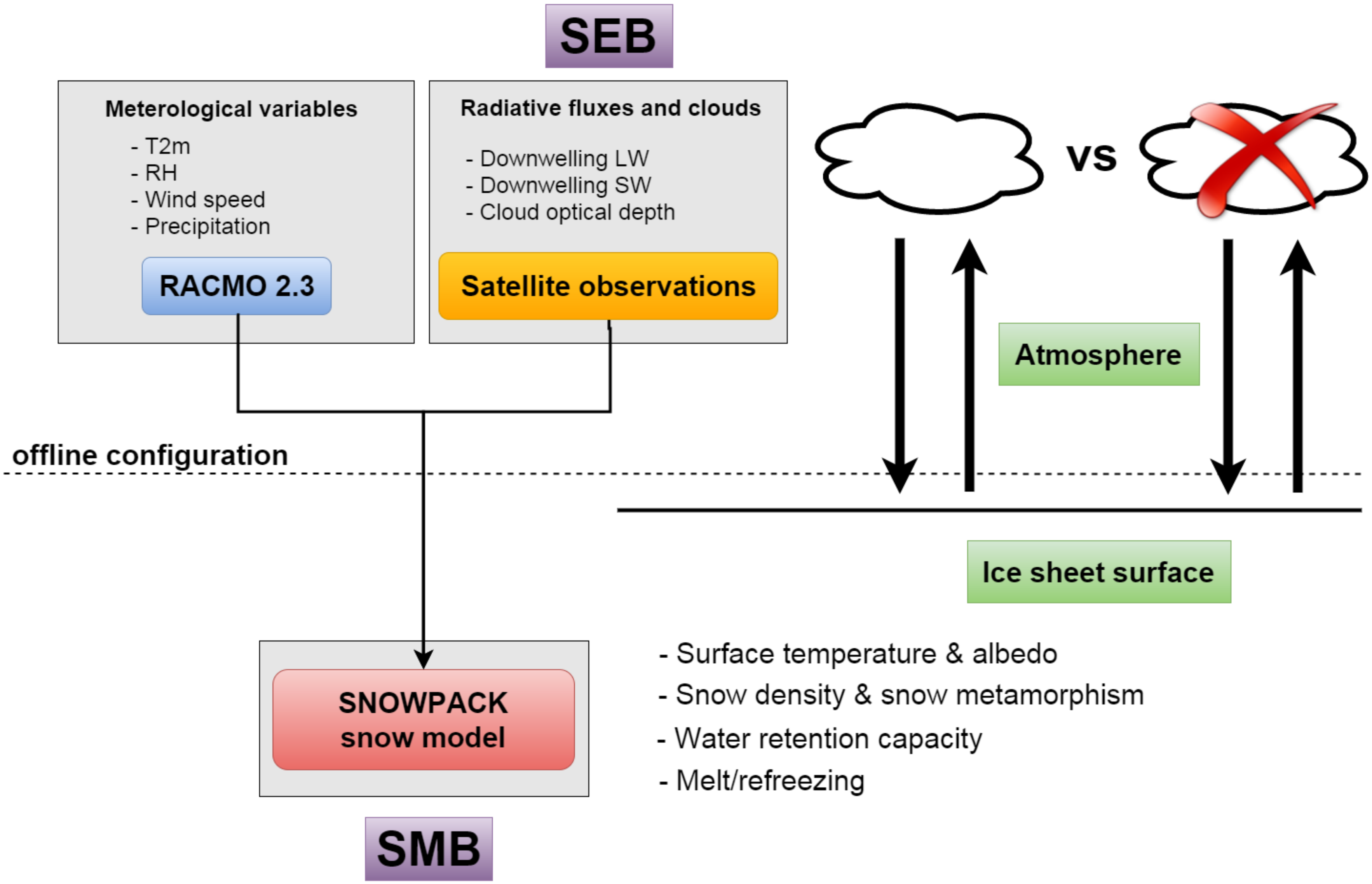


Mean CRE = 29.5 ± 5.2 W m^{-2}

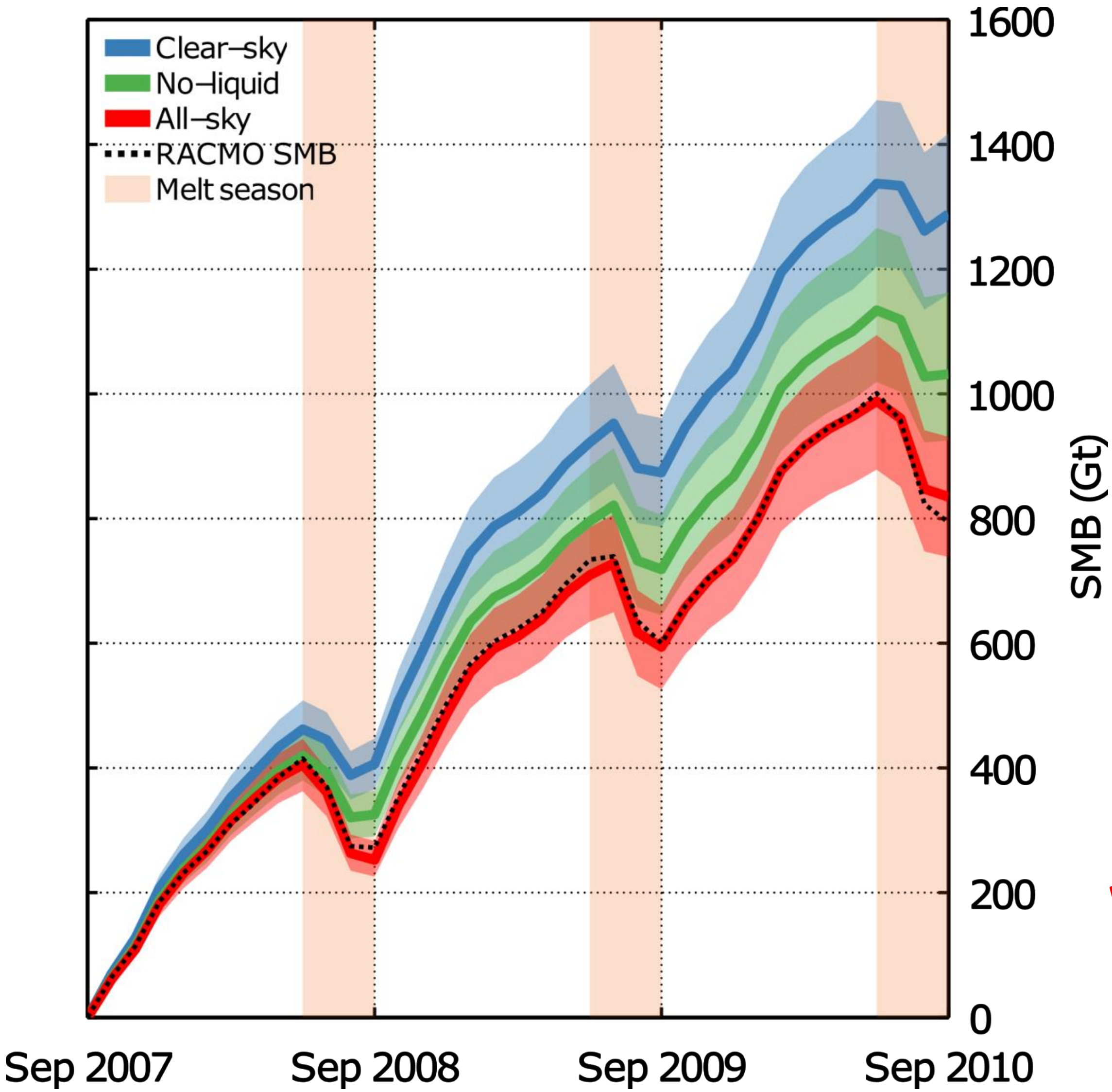
What does this mean for the SMB?

Van Tricht et al., 2015 (in press)

From SEB to SMB



Cloud impact on SMB

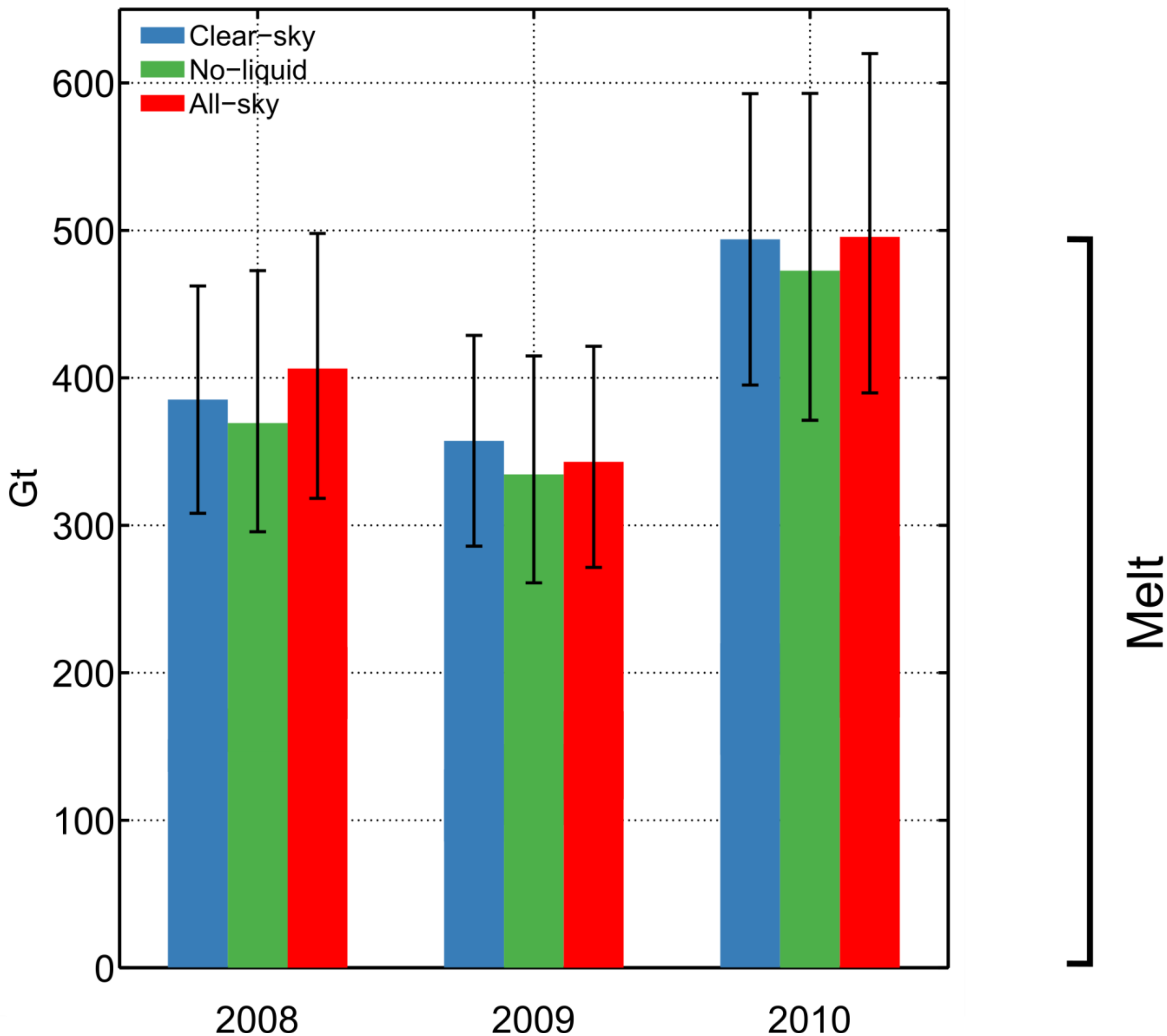


- **152 ±20 Gt y^{-1} lower SMB**
- **35% decrease**
- **Ice and liquid show similar contributions**

Where does this mass go?

Van Tricht et al., 2015 (in press)

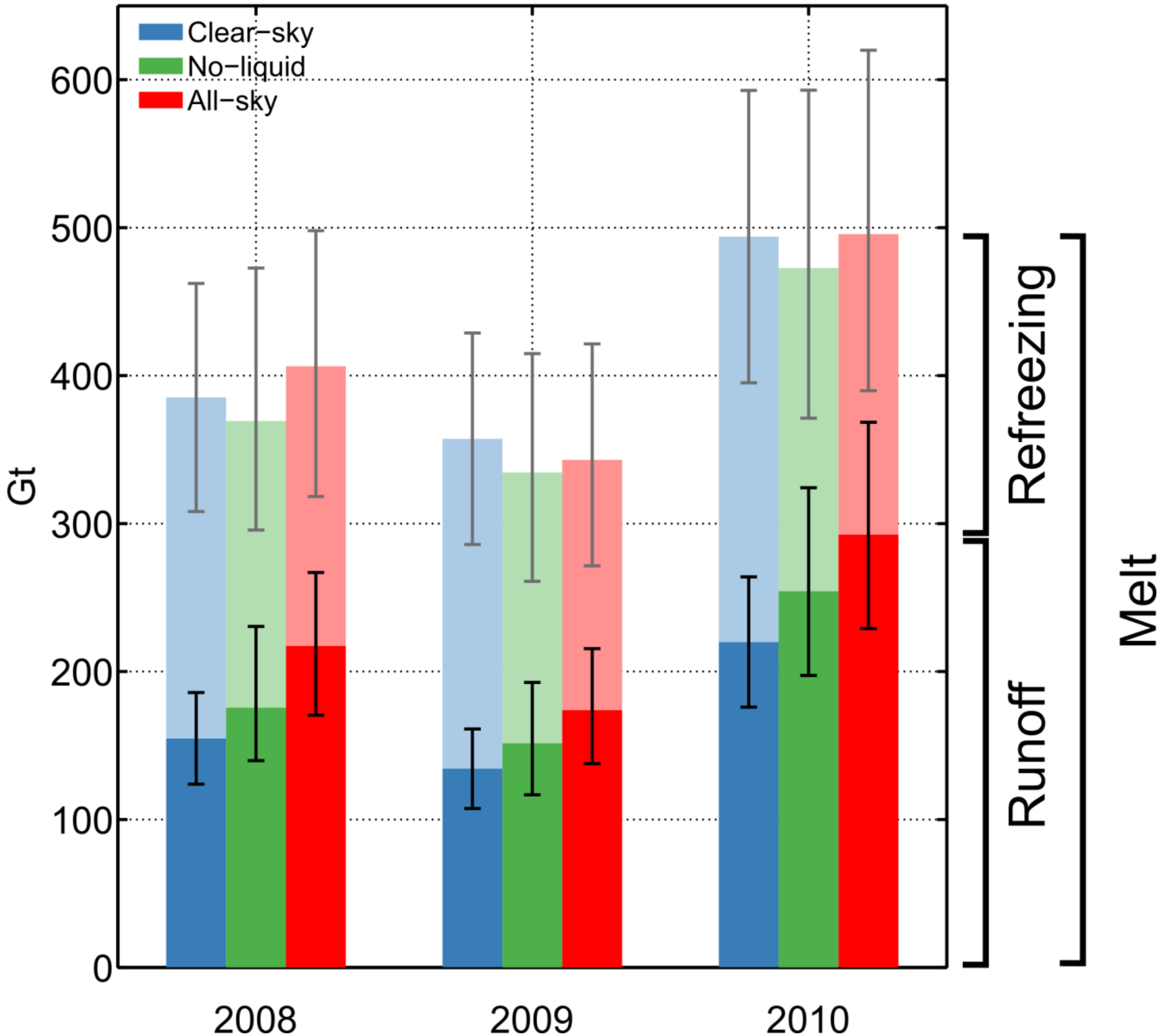
Melt/refreezing/runoff



- **Similar amounts of melt**
- **58% refreezing in clear-sky**
- **45% refreezing in all-sky**

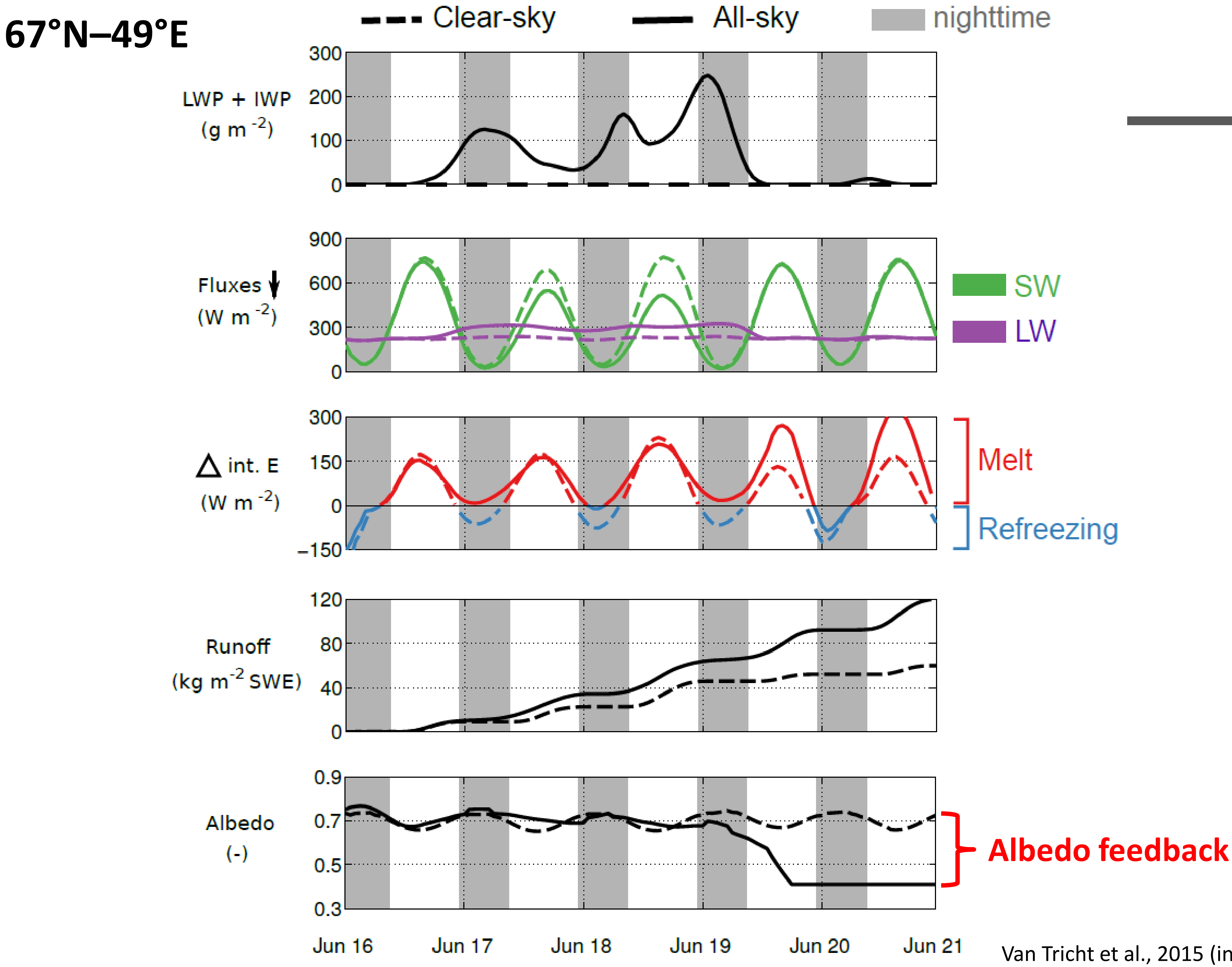
Van Tricht et al., 2015 (in press)

Melt/refreezing/runoff



- Meltwater runoff enhanced by 56 ±20 Gt y^{-1}
- = one-third increase
- 25 Gt due to cloud ice water
- 32 Gt due to cloud liquid water

Van Tricht et al., 2015 (in press)



Van Tricht et al., 2015 (in press)


07/05/2008
Spring
0
250
500
750
1000
1250
Difference in surface mass balance (kg m² SWE)
due to clouds
Image IBCAO
Image Landsat
Image U.S. Geological Survey
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

Conclusion and outlook

- Cloud radiative effect estimates using satellite observations show on average **cloud warming**
- Coupling to SMB requires an **integrated** hybrid satellite-climate model approach and a snow model
- Clouds enhance Greenland ice sheet meltwater runoff due to **reduced refreezing**, not by enhancing melt directly

- Cloud representations in climate models need to be further improved in order to look at future cloudiness and ice sheet response

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Contact: Kristof.VanTricht@ees.kuleuven.be

Further reading:

Van Tricht, K., Lhermitte, S., Lenaerts, J.T.M., Gorodetskaya, I.V., L'Ecuyer, T., Noël, B., van den Broeke, M.R., Turner, D.D., van Lipzig, N.P.M. **Clouds enhance Greenland ice sheet meltwater runoff**. *Nature Communications* [in press]

Satellite observations merged with regional climate model to increase temporal resolution

'Hybrid' satellite-climate model dataset

Cloud observations → SEB

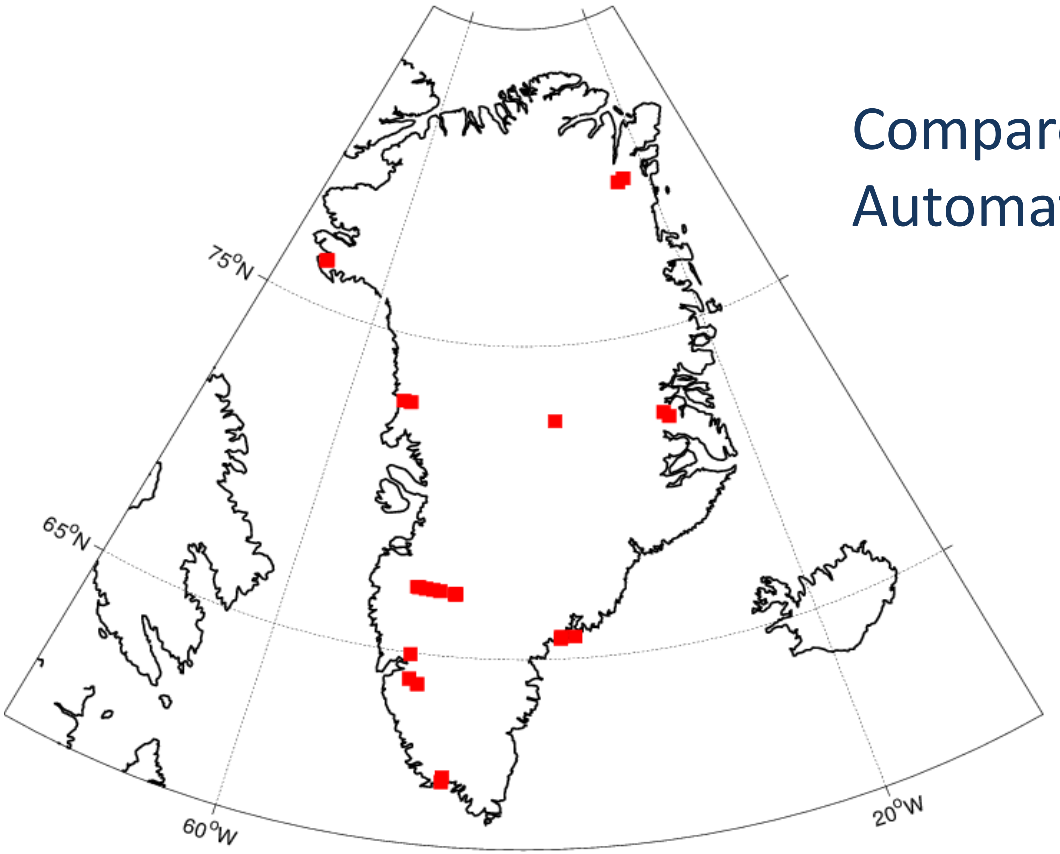
1B-CPR	2B-CLDCLASS	2B-CLDCLASS-LIDAR	2B-CWC-RO	2B-CWC-RVOD	2B-FLXHR
2B-FLXHR-LIDAR	2B-GEOPROF	2B-GEOPROF-LIDAR	2B-TAU	2C-ICE	2C-PRECIP-COLUMN
2C-RAIN-PROFILE	2C-SNOW-PROFILE	2D-CLOUDSAT-TRMM	ECMWF-AUX	MODIS-AUX	

2B-FLXHR-LIDAR = Level 2B Fluxes and Heating Rates

Algorithm that uses
  Coupled **CloudSat/CALIPSO/MODIS/ECMWF data**
To calculate
  LW/SW Radiative fluxes and heating rates at 126 vertical levels

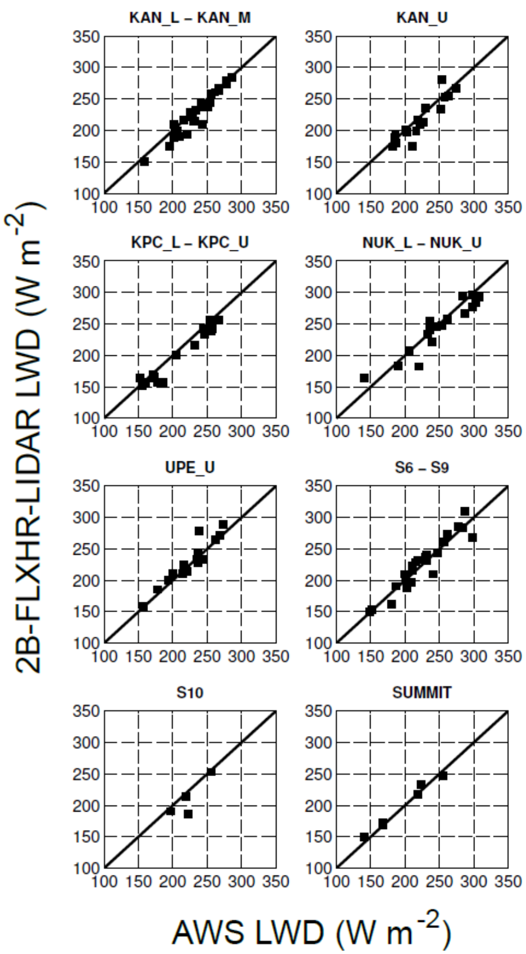
Radiative flux evaluations

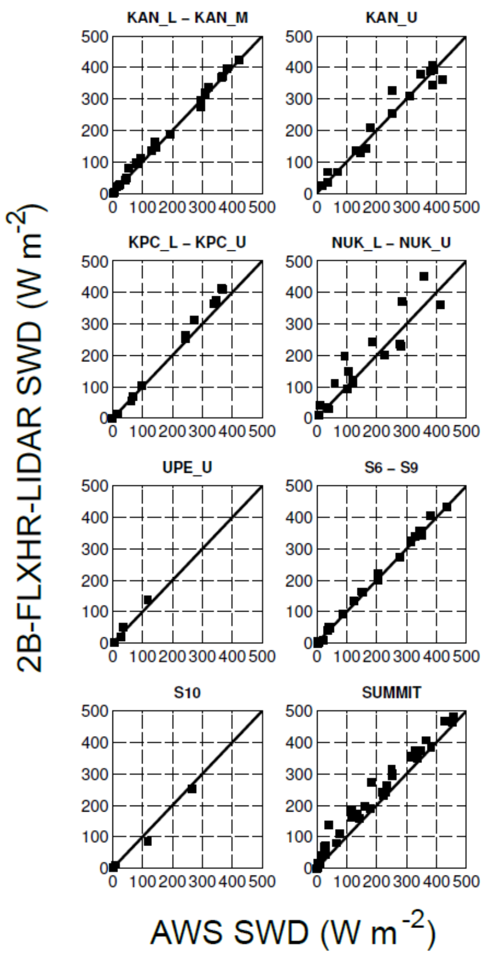
IMAU and GC-Net stations



Compare to
Automatic Weather Stations (AWS)

Radiative flux evaluations

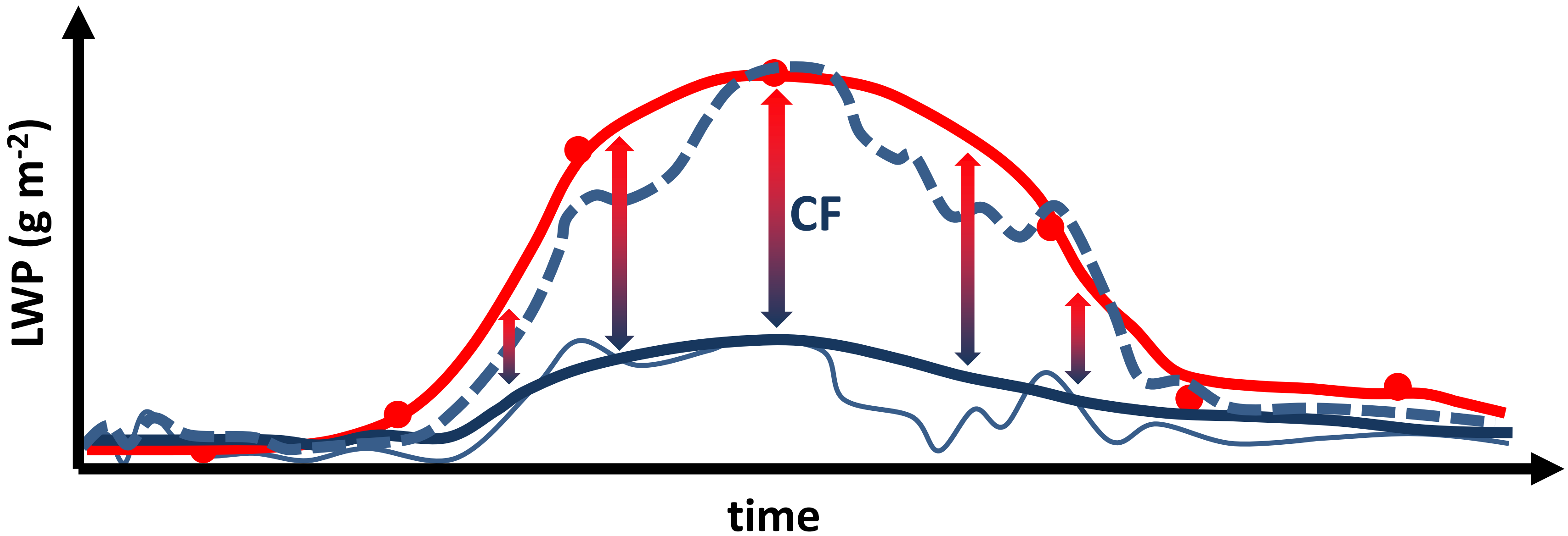




	LWD		SWD	
AWS ID	**Bias**	**RMSE**	**Bias**	**RMSE**
KAN_L - KAN_M	-7.4	12.3	8.0	18.6
KAN_U	-5.3	13.8	1.6	30.0
KPC_L - KPC-U	-8.7	12.6	11.8	20.5
NUK_L - NUK-U	-5.3	16.0	16.0	50.7
UPE-U	3.9	12.4	6.6	13.3
S6 - S9	1.1	12.9	4.9	9.7
S10	-12.7	19.0	-11.4	17.2
SUMMIT	2.2	6.2	23.4	33.6
Average	**-4.0**	**13.2**	**7.6**	**24.2**

Van Tricht et al., 2015 (in press)

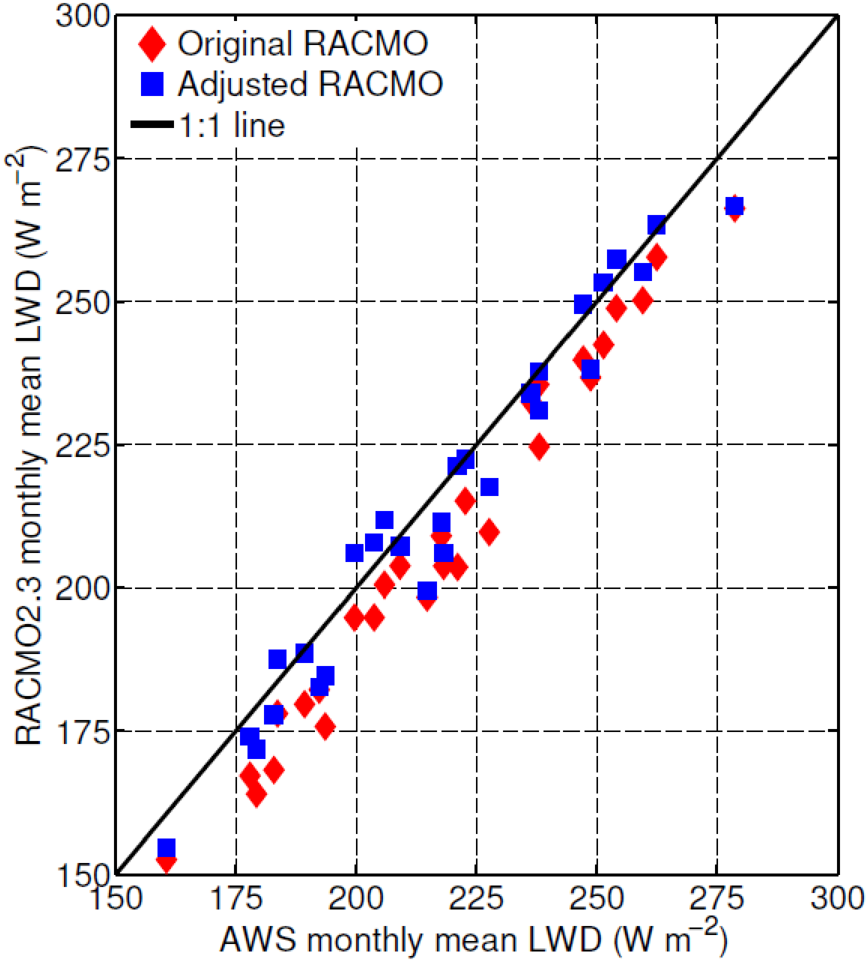
LWP/IWP correction

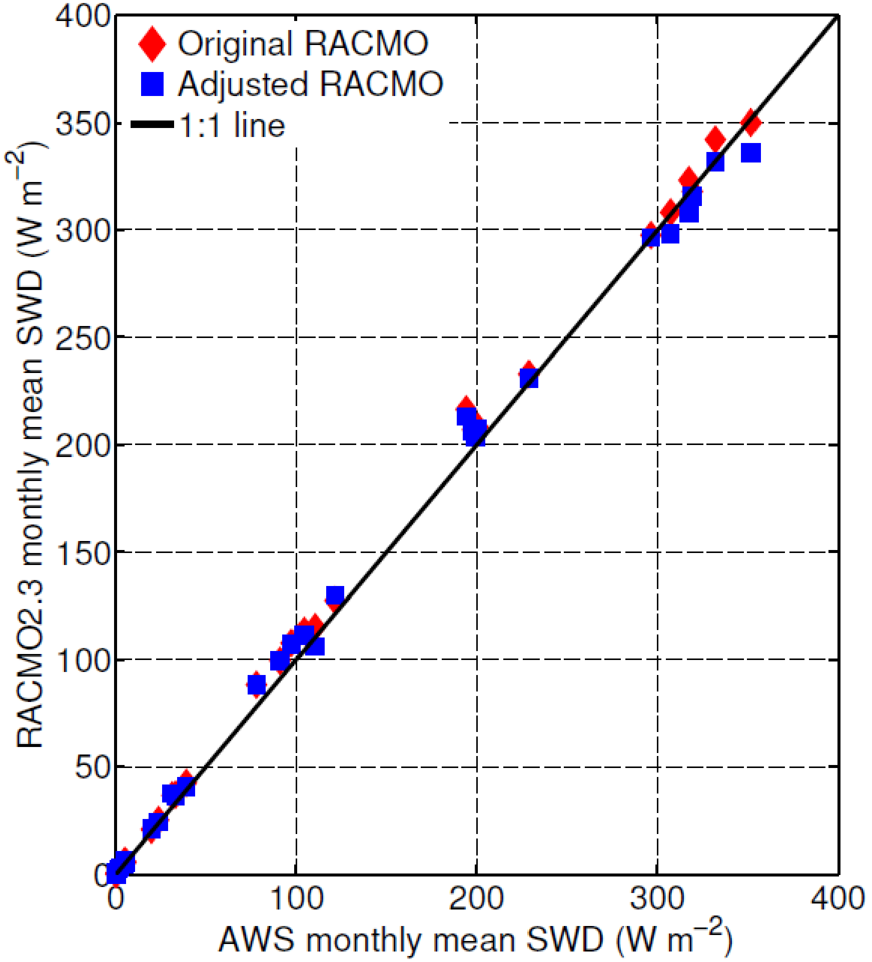


$$LWP_{i,corrected} = LWP_{i,original} + CF \times (1 - exp(-P \times LWP_{i,original}))$$

Van Tricht et al., 2015 (in press)

Evaluation of hybrid product





LW

Bias = -3.2 W m^{-2} (was -9.9)
RMSE = 6.8 W m^{-2} (was 10.9)

SW

Bias = 1.8 W m^{-2} (was 4.4)
RMSE = 6.6 W m^{-2} (was 6.6)